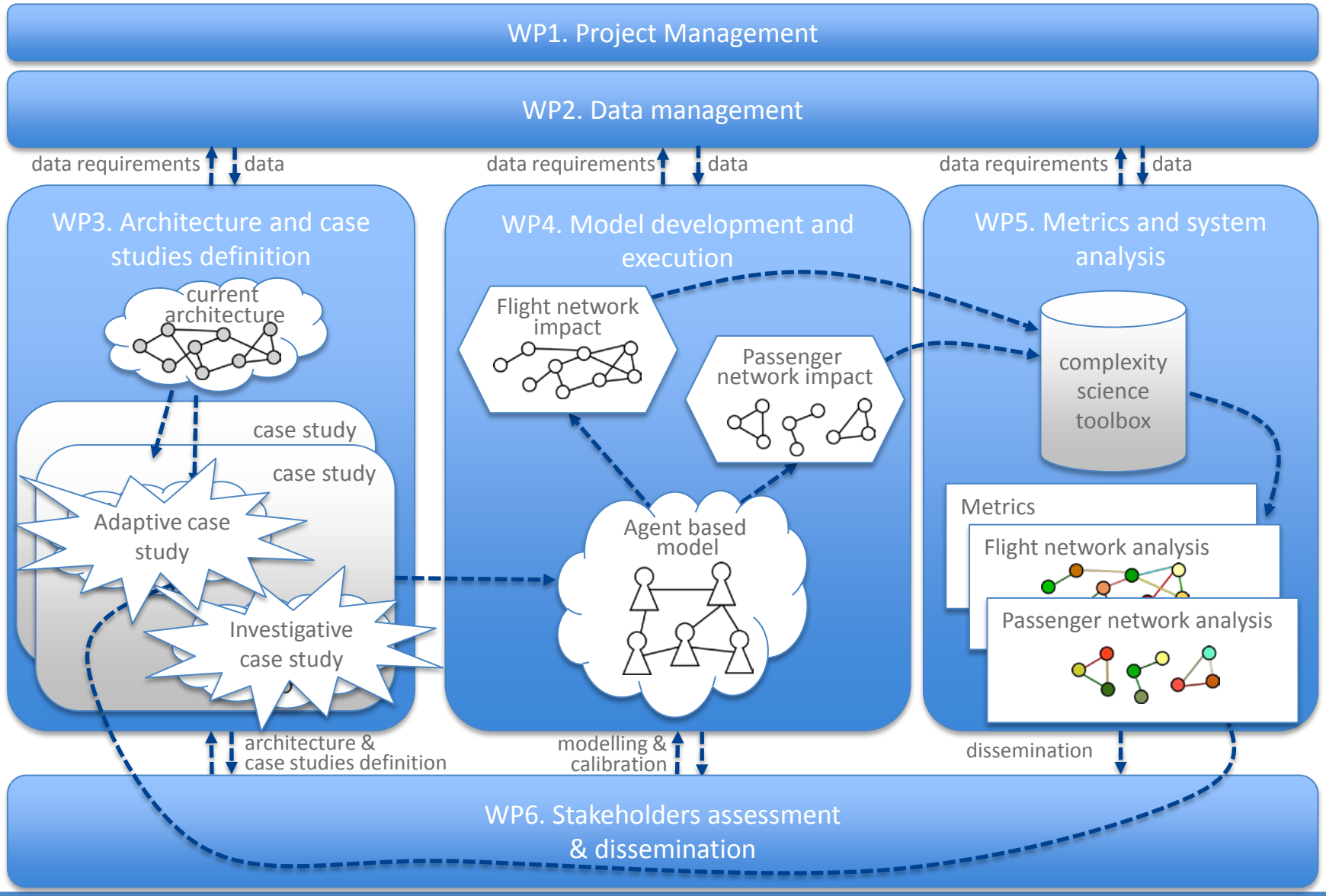
Domino – Model approach

SESAR JOINT UNDERTAKING

Founding Members

EUROPEAN UNION EUROCONTROL

Model approach



Expected benefits for stakeholders

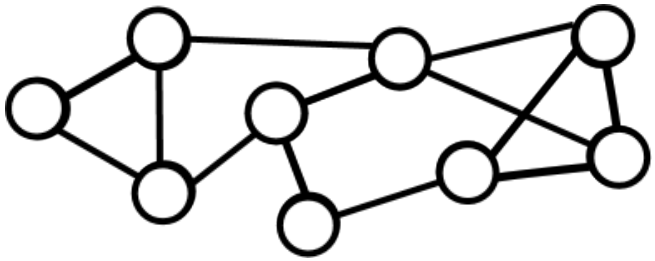
Stakeholder	Benefit
ATM system architects	• Gain a better understanding on the impact of changes in the system • Identification of hotspots in the network which propagate delay/cost for airlines and passengers • Have a methodology to test new mechanism and their deployment
Policy makers	• The ABM model captures stakeholder behaviour allowing to test changes in policies and not only on technical solutions
Airspace Users	• Estimate impact of system changes on their metrics (delay and costs) • Identify the relationship between elements in the ATM network • Identify hotspots at network level and non-direct relationships between the elements in the system • Evaluate different flight operation policies
Network Manager	• Identify impact of local changes at network level with non-direct interaction • Quantify the impact of different solutions and deployment modes
Airport	• Understand their criticality and position in the ATM network • Consider the impact of EAMAN/DMAN on the ATM system • Quantify their connectivity and the impact of local solutions at network level (ground and air)
Passengers	• Being considered when designing the system as their metrics can be explicitly estimated

Model approach

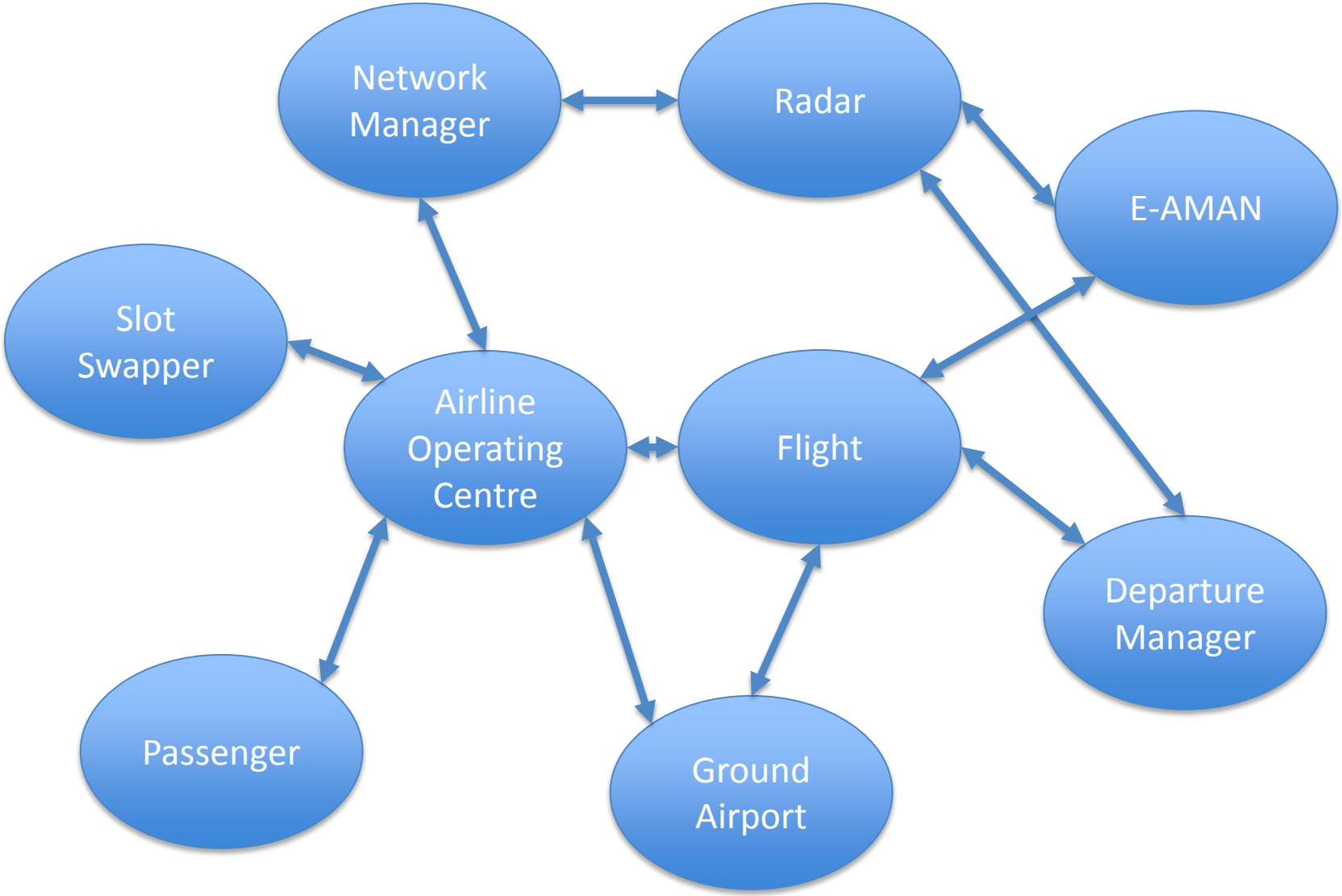
Contrasting stakeholder perspectives

Flight

Passenger



Model approach



Model approach

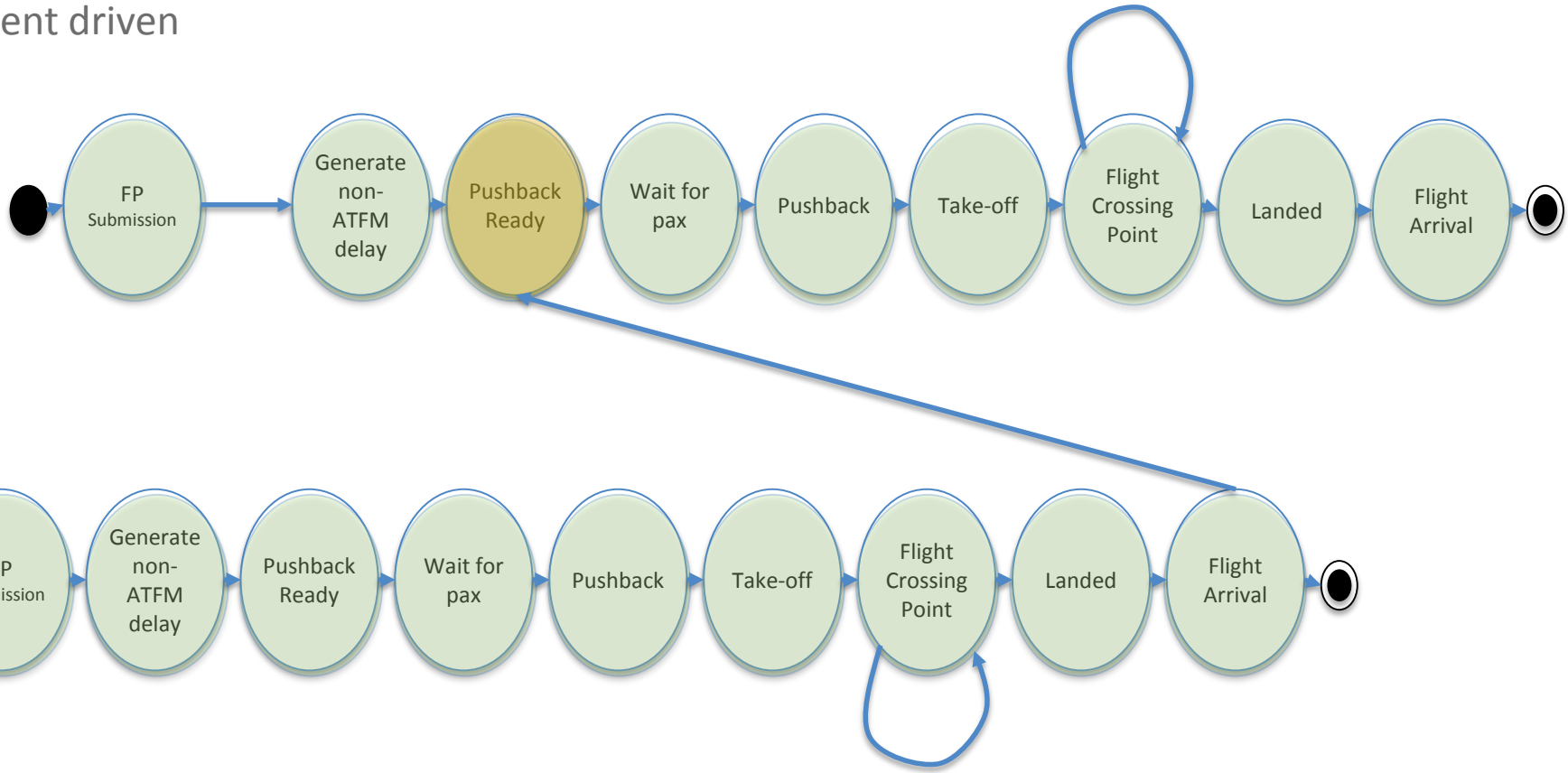
Event	When?	What is done?	Agents involved
FP submission	SOBT – 3h	• Flight plan computation • Request ATFM slot • Slot swapping	• AOC • NM (Radar)
Generate non-ATFM delay	EOBT – 1h	• Generate delay not explicitly modelled	• AOC
Pushback ready	EOBT	• Request departure slot DMAN	• Flight • DMAN • Ground Airport
Waiting for passengers	EOBT	• Assess if waiting for passengers	• AOC
Pushback	AOBT	• Rebook passengers missed connection • Decide if speed up flight	• AOC

Model approach

Event	When?	What is done?	Agents involved
Take-off	Take-off	• Triggers computation of flight	• Flight
Flight crossing point	Relevant points	• TOC: reassess speed adjustment • EAMAN planning horizon: expected delay (adjust speed) • EMAN tactical horizon: holding delay	• Flight (Radar) • EAMAN • AOC
Landed	Landing	• Compute taxi-in time	• Flight • Ground Airport
Flight arrival	AIBT	• Connect passengers to following flights • Compute turnaround • Reassess departure delay	• AOC • Ground Airport

Model approach

Event driven



Model approach

```
Preparing aircraft for simulation... executed in 0:00:00.006683
Preparing pax for simulation... executed in 0:00:00.016914
Preparation executed in 0:00:00.024508
World is ready!

Starting simulation at: 2019-02-15 17:21:07.571546

AOC 891 starts flight plan submission for flight 1074 at t= 180.0
AOC 891 computes the flight plan options for flight 1074
AOC 891 is creating the possible flight plans for flight 1074
NM received an ATFM request from AOC 891
Computing atfm delay of flight plan FP 13e61088-f7b1-477d-88f0-c56b72a4cbca
Flight not affected by explicit arrival regulation - use probabilistic model
NM considers flight plan submission from AOC 891 for flight 1074
EAMAN 565 request tracking of flight 1074
EAMAN 565 asks updates to radar for flight_uid 1074
Radar subscription added for agent_uid 565 regarding flight 1074
EAMAN 565 updates its planned queue with flight 1074
NM accepted FP 13e61088-f7b1-477d-88f0-c56b72a4cbca with ATFM delay: 0.0
EOBT update for flight 1074 (new_eobt: 360.0 ) at t= 180.0
AOC 879 starts flight plan submission for flight 1076 at t= 190.0
AOC 879 computes the flight plan options for flight 1076
AOC 879 is creating the possible flight plans for flight 1076
NM received an ATFM request from AOC 879
Computing atfm delay of flight plan FP 6c23998f-426f-49a1-813f-0b96dff190ab
Flight not affected by explicit arrival regulation - use probabilistic model
NM received an ATFM request from AOC 879
Computing atfm delay of flight plan FP 4f9caa95-1f1f-45e7-85f3-85ddf0dd60f4
Flight not affected by explicit arrival regulation - use probabilistic model
NM received an ATFM request from AOC 879
```

Model approach

```
Flight 2770 finished segment at 1184.387678691506 4
Flight 3038 finished segment at 1184.393910084228
Flight 3038 landed at 1184.393910084228
Flight 3038 sends taxi in time request
Airport 180 received taxi-in time request from flight 3038
Flight 3038 starts taxiing-in at 1184.393910084228
Flight 1118 finished segment at 1184.571562027751
Flight 1118 holding 0 using fuel kg 0.0
Flight 1118 TIME LANDING  1198.028665593642 7
Flight 1092 finished segment at 1184.6649102057866
Flight 2629 finished segment at 1184.7042332812496
Flight 1270 finished segment at 1184.7487923754716
Flight 2088 finished segment at 1184.756427063933
Flight 2715 finished segment at 1184.7811953234873
EAMAN 330 received flight update for flight 1196
EAMAN 330 sees flight 1196 entering its execution horizon
EAMAN - QUEUE AT EXECUTION HORIZON
Update flight plan constraint, landing time 1196 delay: 0 clt: 1202.
Flight 1196 finished segment at 1184.8923728615039
Flight 1196 holding 0 using fuel kg 0.0
Flight 1196 TIME LANDING  1202.3822510614775
```

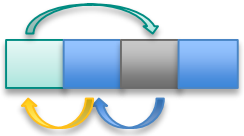
Model approach

```
Computing atfm delay of flight plan FP c5669e4e-ef94-4189-bcf1-018e2bf46fcc
Flight not affected by explicit arrival regulation - use probabilistic model
ATFM delay value: 18.0
NM considers flight plan submission from AOC 940 for flight 1501
EAMAN 384 request tracking of flight 1501
EAMAN 384 asks updates to radar for flight_uid 1501
Radar subscription added for agent_uid 384 regarding flight 1501
EAMAN 384 updates its planned queue with flight 1501
NM accepted FP c5669e4e-ef94-4189-bcf1-018e2bf46fcc with ATFM delay: 18.0
EOBT update for flight 1501 (new_eobt: 558.0 ) at t= 360.0
Push-back ready triggered for flight 1074 at t= 360.35734005273787
Flight 1074 sends taxi out time estimation request
Airport 221 received taxi-out time estimation request from AOC 1074
Flight 1074 is waiting push-back at gate
Flight 1074 sends taxi out time request
Airport 221 received taxi-out time request from AOC 1074
Pax to board for 1074 : [Pax group 0 with 212 pax]
AOC 891 blames 1074 for the DOC cost: 0.0 of Pax group 0 with 212 pax
AOC 891 is sending cost blame to: 1074 for cost: 0.0 as DOC
Pax group 0 with 212 pax has been cared for ( 0.0 euros in total) for a delay
Pax group 0 with 212 pax now blames compensation on flight 1074
Pax already at airport left behind by 1074 : []
do_reallocation triggered from check_push_back of flight 1074 for paxs: [] at
Flight 1074 starts taxiing-out at 360.35734005273787
AOC 1045 starts flight plan submission for flight 1184 at t= 365.0
AOC 1045 computes the flight plan options for flight 1184
AOC 1045 is creating the possible flight plans for flight 1184
NM received an ATFM request from AOC 1045
Computing atfm delay of flight plan FP d38dfa67-a2c8-4afa-aecf-5f7e22e7fe95
Flight not affected by explicit arrival regulation - use probabilistic model
NM considers flight plan submission from AOC 1045 for flight 1184
```

Mechanisms

- **4D Trajectory Adjustment (4DTA)**

- **Flight Prioritisation (FP)**



- **Flight Arrival Coordination (FAC)**

Level 0
Current

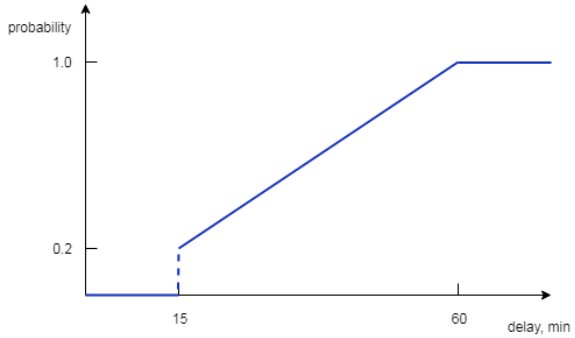
Level 1
Improved

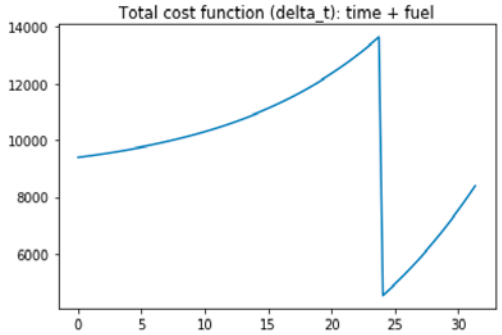
Level 2
Futuristic

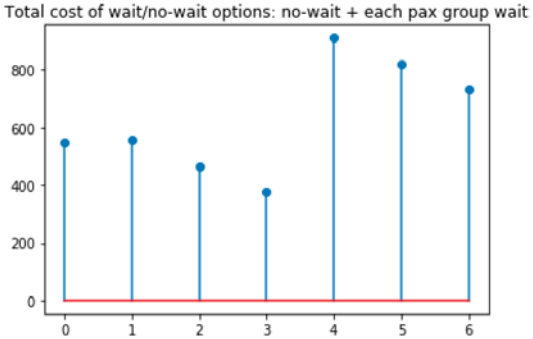
Mechanisms

4D Trajectory Adjustment

Rationale	Implementation	
Delay management strategies from the Airline Operations point of view	Level 0	• Basic delay recovery rules linked to amount of delay incurred • Cost index computed before departure • Limited waiting for passengers (only premium pax, max 15 min)
	Level 1	• Delay recovered based on expected costs • Cost index computed at TOC • Waiting for passengers based on expected cost
	Level 2	• Delay recovered based on expected costs • Cost index computed at gate and at TOC • Wait for passengers based on expected cost considering DCI

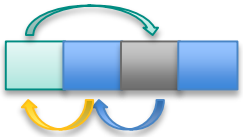






Mechanisms

Flight Prioritisation



Rationale	Implementation	
Collaborative decision making considering airlines prioritisation of their flights to minimise their expected cost	Level 0	• No pre-departure prioritisation of flights by AU • FPFS during ATFM regulations • No slot swapping
	Level 1	• Pre-departure prioritisation of flights by AU • Allow intra-airline slot swaps for given arrival ATFM regulations
	Level 2	• Pre-departure prioritisation of fights by AU • Allow inter-airline slot swaps for given arrival ATFM regulations

Mechanisms

Flight Arrival Coordination

Rationale	Implementation	
Tactical management of arrival at airports doing sequencing and merging with planning capabilities	Level 0	• EAMAN assign arrival slots in a FIFO approach • Focus on minimisation of holding delay
	Level 1	• EAMAN request from flights: when delay is high enough to be propagated as reactionary delay • Focus on minimisation of landing delay + reactionary delay
	Level 2	• EAMAN request from flights (from AOC): expected total cost associated with available slots • Focus on minimisation of expected costs

Scenarios

Investigative case studies

- Variables considered to build the scenarios:
    - 4D Trajectory Adjustment [Level 0, Level 1, Level 2]
    - Flight Arrival Coordination [Level 0, Level 1, Level 2]
    - Flight Prioritisation [Level 0, Level 1, Level 2]
    - Buffers [Default, Low]
    - Delays [Default, High]

Variables combined into 32 scenarios

Scenarios

Baseline scenarios

Sub-scenario	4D Trajectory Adjustment	Flight Arrival Coordination	Flight Prioritisation	Delays
Default baseline	Default	Default	Default	Default
Stressed baseline	Default	Default	Default	High

Scenarios

High priority scenarios

Sub-scenario	4D Trajectory Adjustment	Flight Arrival Coordination	Flight Prioritisation	Delays
Default tactical adjustments	Level 2	Level 2	Default	Default
Stressed tactical adjustments	Level 2	Level 2	Default	High
Default synergy	Level 2	Level 2	Level 2	Default
Stressed synergy	Level 2	Level 2	Level 2	High